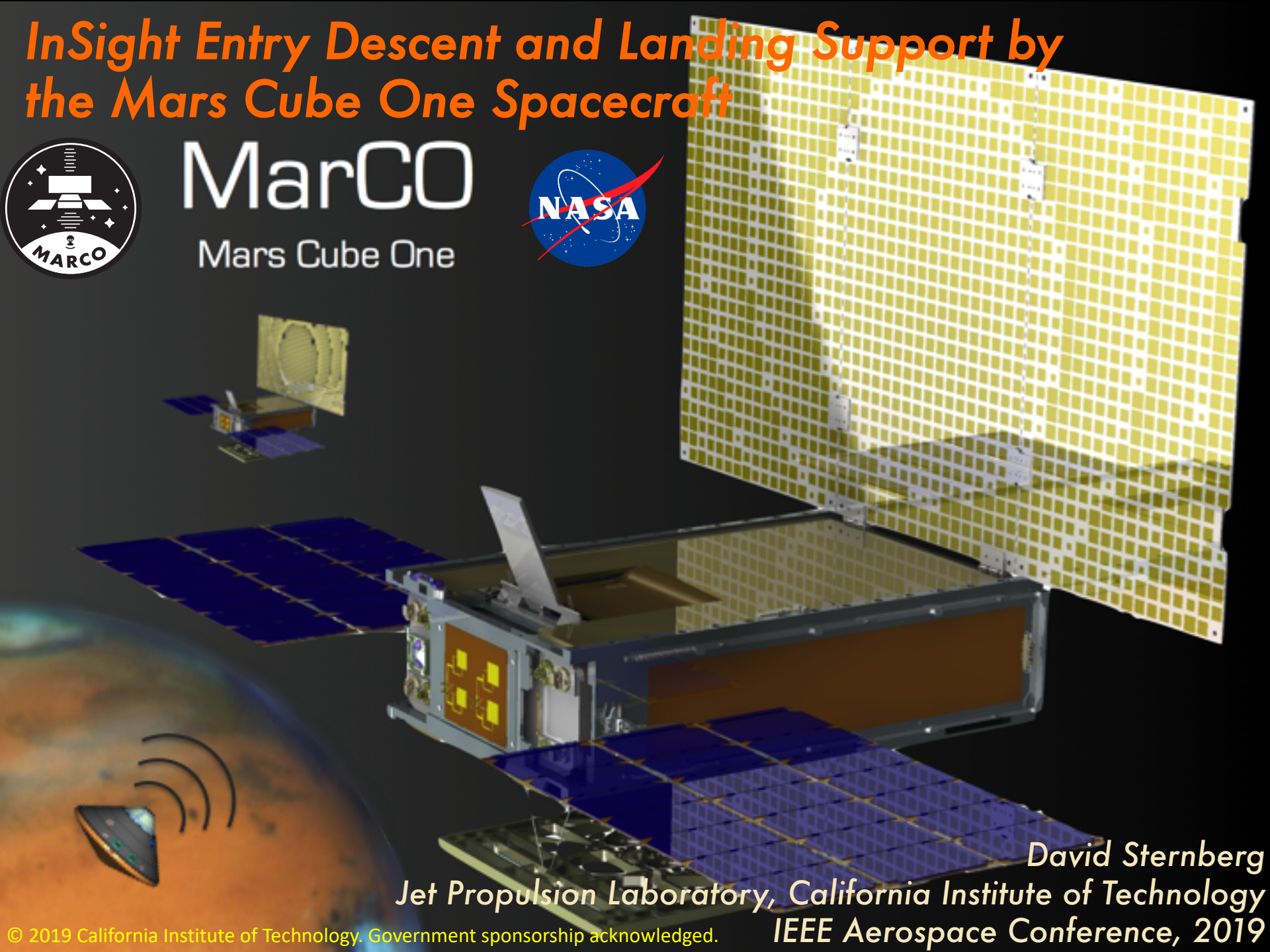
InSight Entry Descent and Landing Support by the Mars Cube One Spacecraft

MarCO

Mars Cube One



David Sternberg
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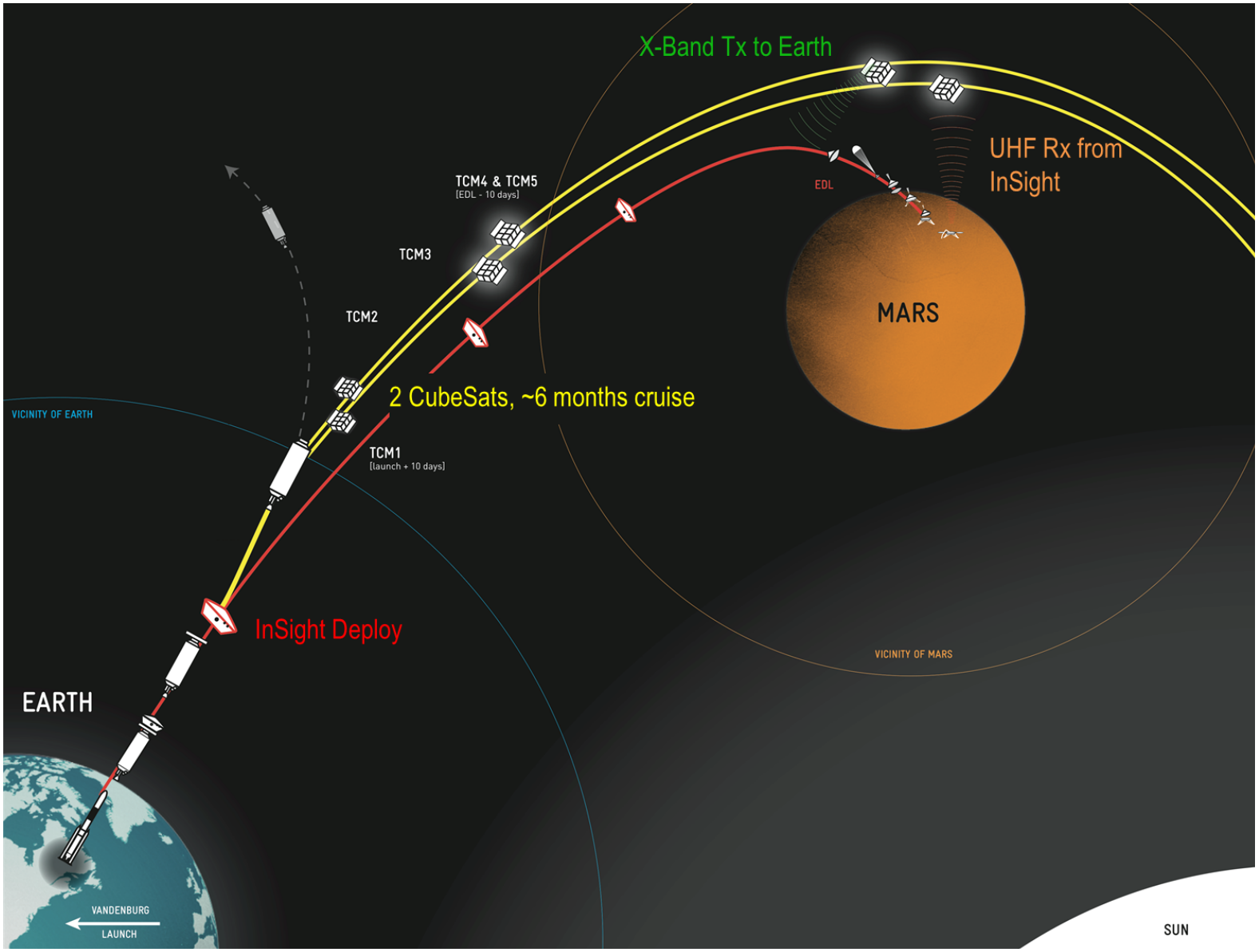
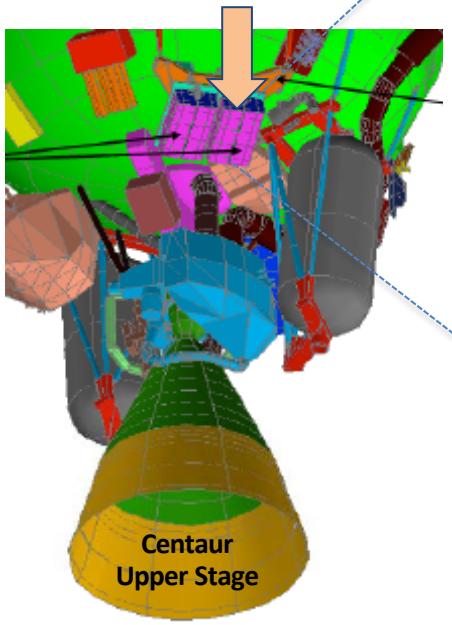
IEEE Aerospace Conference, 2019

MarCO Mission Summary



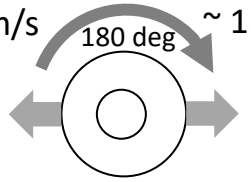
MarCO Mission Summary

1) *Deploy MarCO-A & -B from Tyvak Dispensers (Twins for redundancy)*



MarCO-A
~ 1.5 m/s

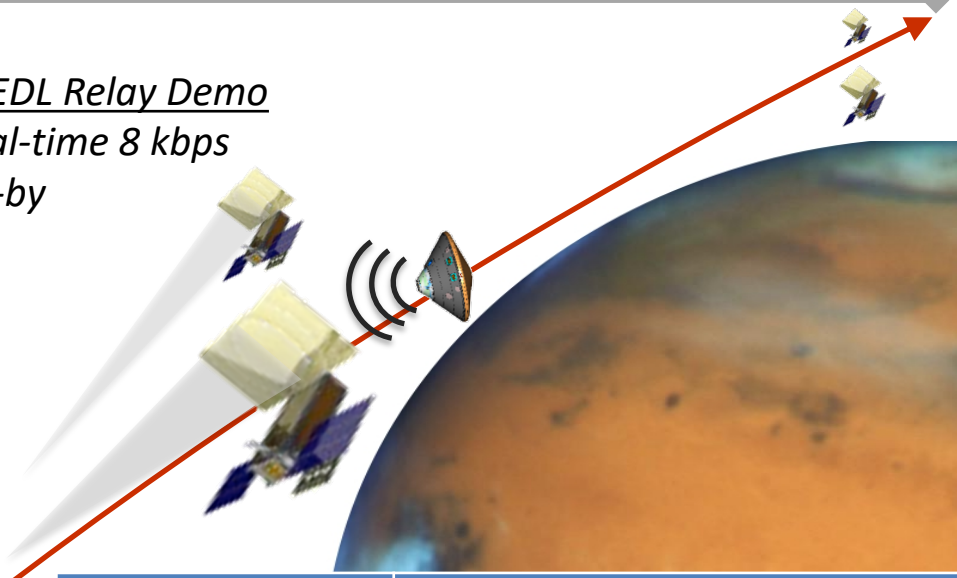
MarCO-B
~ 1.5 m/s



Earth

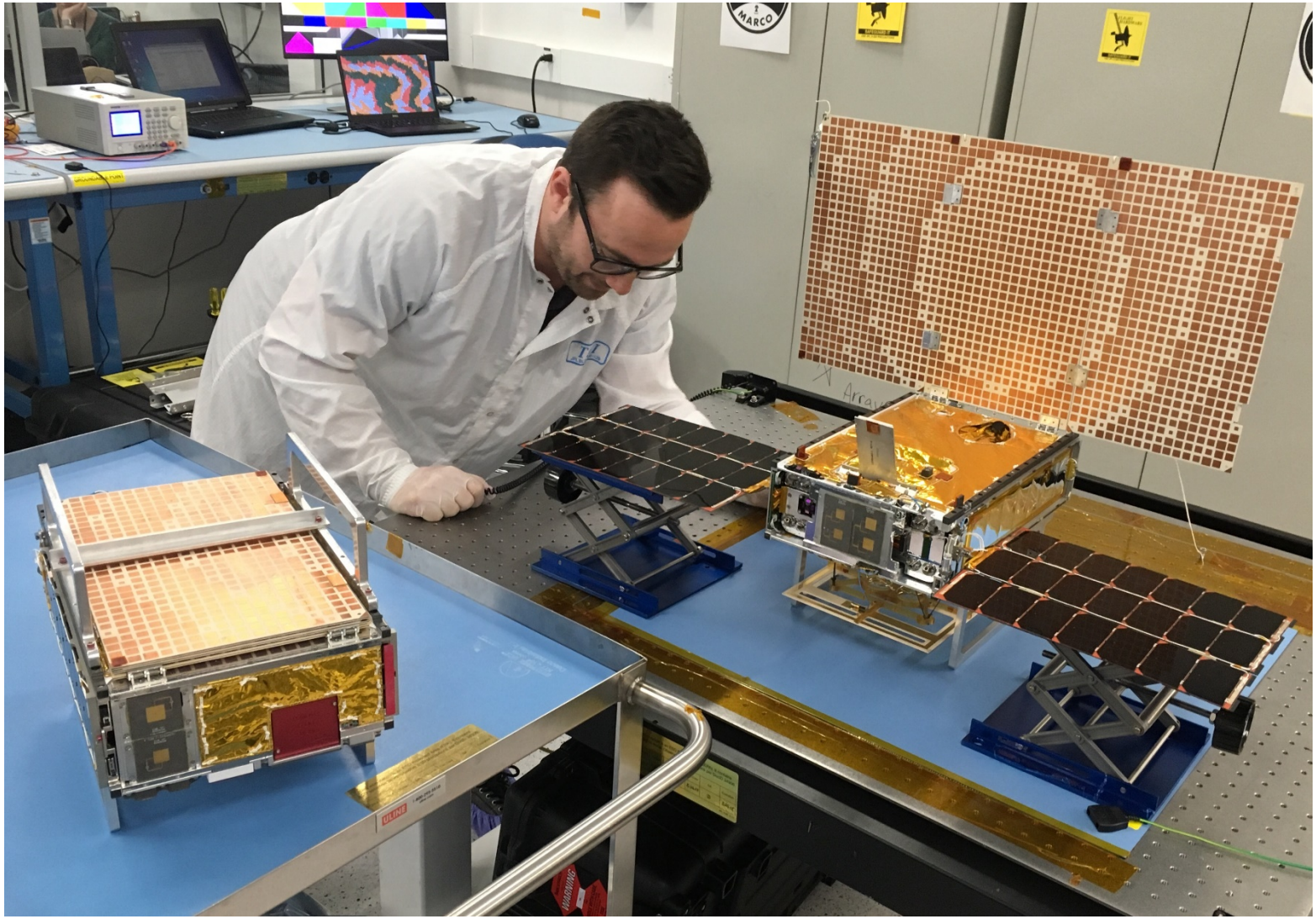
2) Early Cruise Tech Demo Of Telecom and TCM Technologies

3) EDL Relay Demo Real-time 8 kbps Fly-by

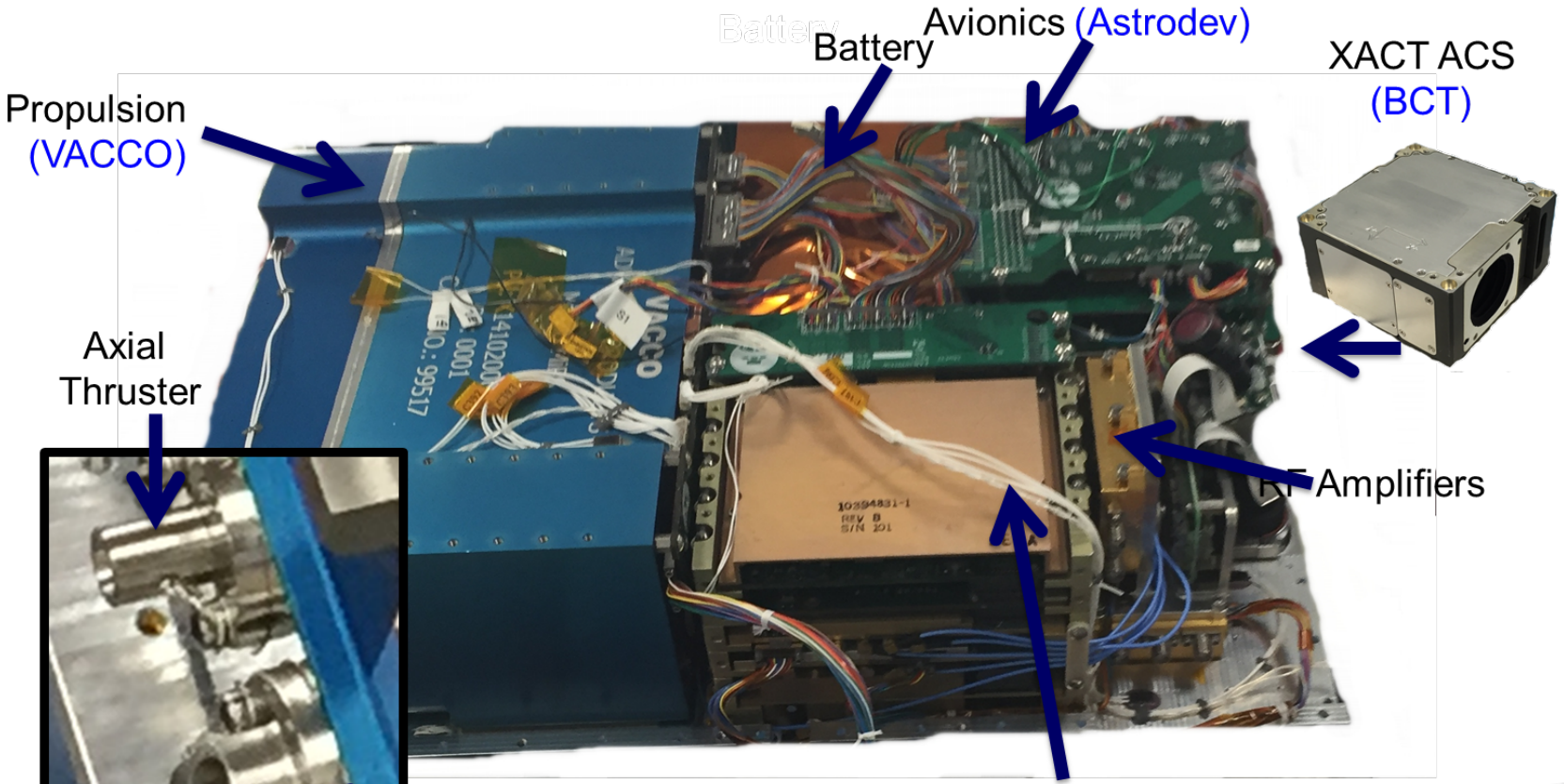


Technology	Mission Objectives
Threshold	
Miniaturized deep space radio (IRIS)	Successful uplink and downlink at multiple data rates + ranging
Flat Panel Antenna	Receipt of telemetry at 8kbps
TCMs on a Cubesat	Execution of TCM 1
Baseline	
Cubesat in deep space	Viable operations beyond Earth orbit
Relay	Bent-pipe during Insight EDL

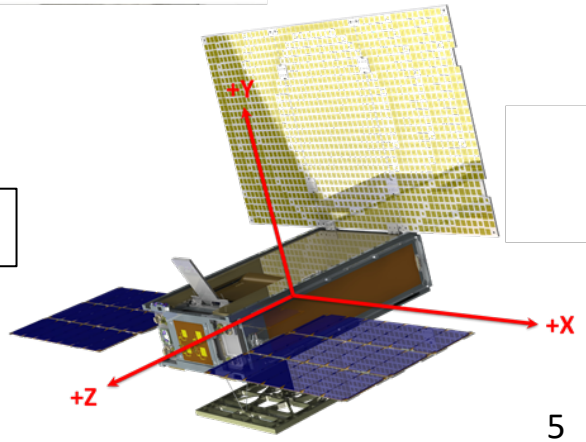
MarCO Spacecraft



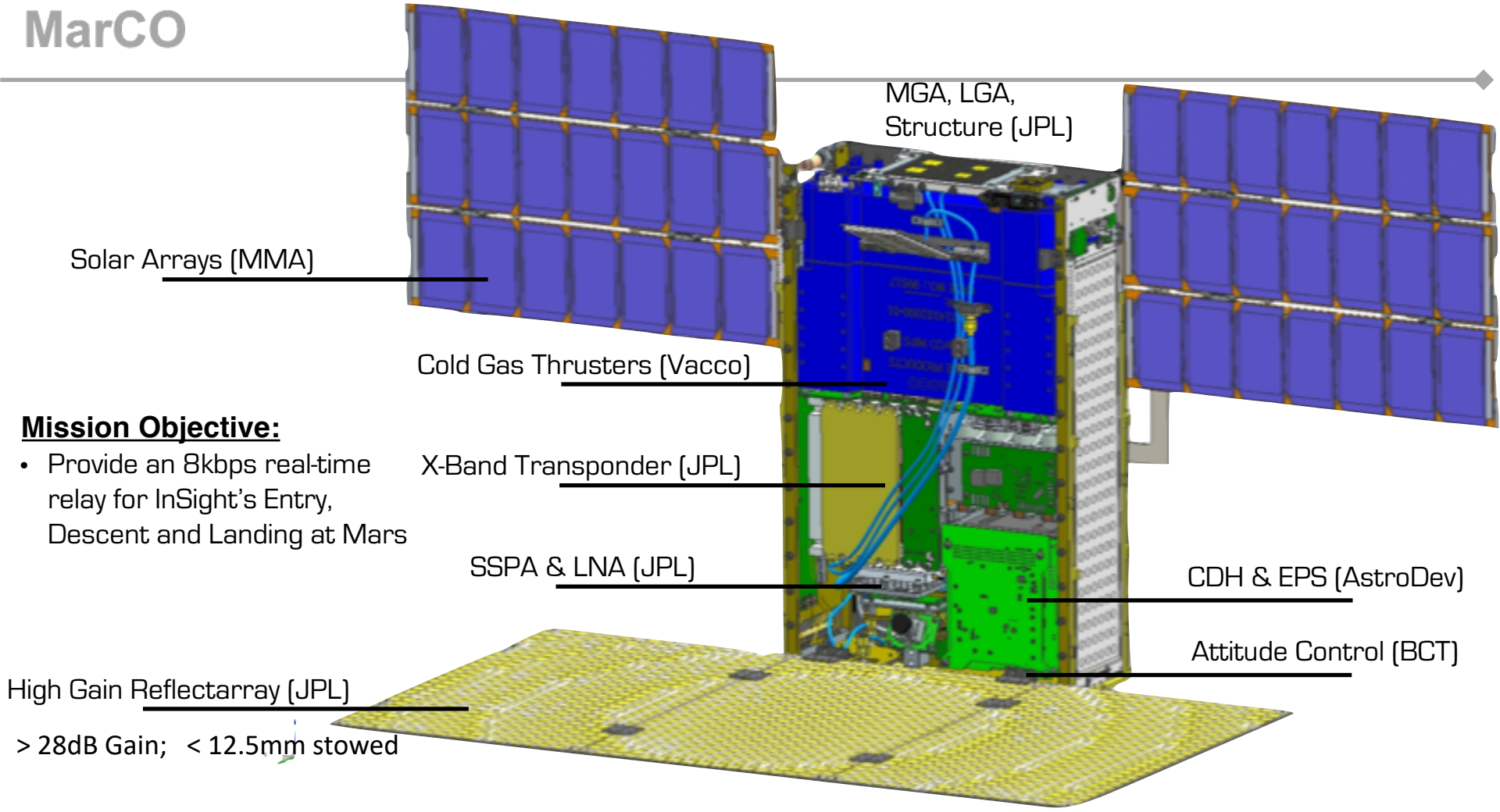
MarCO Internal Components Overview



Not shown: two coarse sun sensors



MarCO



Mission Objective:

- Provide an 8kbps real-time relay for InSight's Entry, Descent and Landing at Mars

MarCO Overview:

Volume: 2 x 6U (12x24x36cm)
Mass: 14.0 kg
Power Generation:
Earth: 35 W
Data Rates: 62-8,000 bps
Delta-V: >40 m/s

Software:

FSW: *protos (JPL)*
GSW: AMPCS (NASA/JPL)

I&T:

In-house S/C I&T, testing,
Tyvak NLAS/Launch Integration

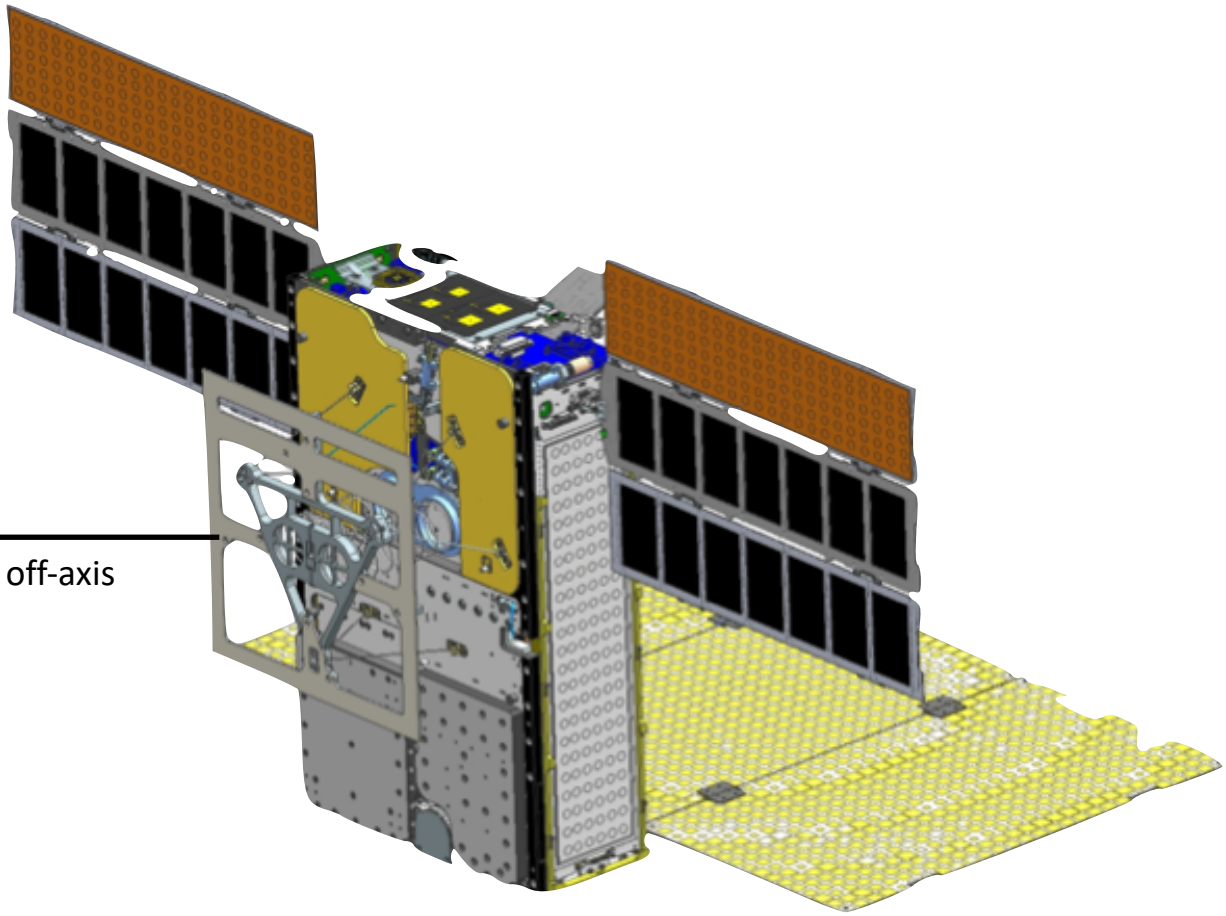
Operations:

Primary: DSN 34m
EDL: Madrid 70m

MarCO

Mission Objective:

- Provide an 8kbps real-time relay for InSight's Entry, Descent and Landing at Mars



MarCO Overview:

Volume: 2 x 6U (10x10x30cm)
Mass: 14.0 kg
Power Generation:
Earth: 35 W
Data Rates: 62-8,000 bps
Delta-V: >40 m/s

Software:

FSW: *protos (JPL)*
GSW: AMPCS (NASA/JPL)

I&T:

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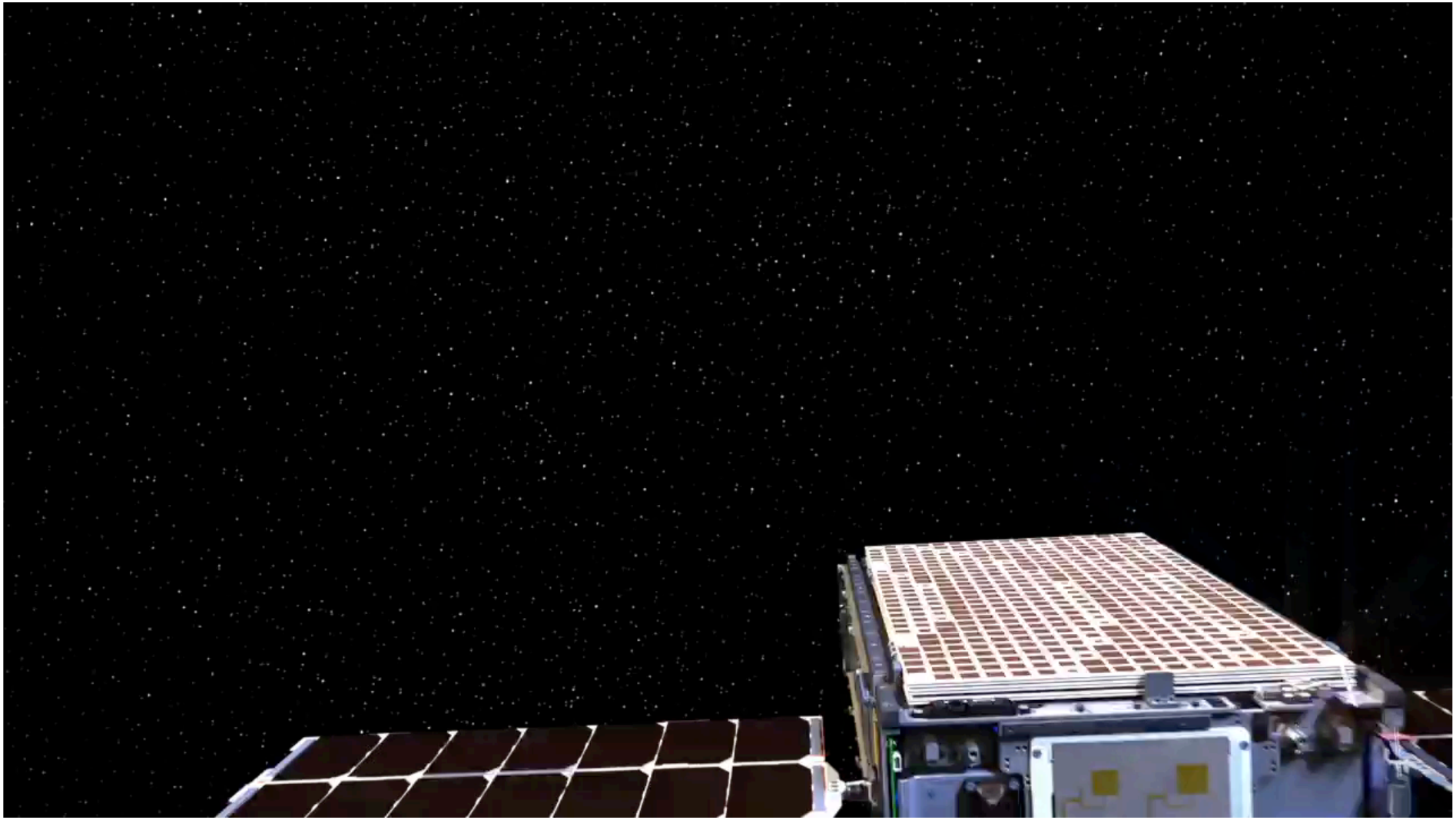
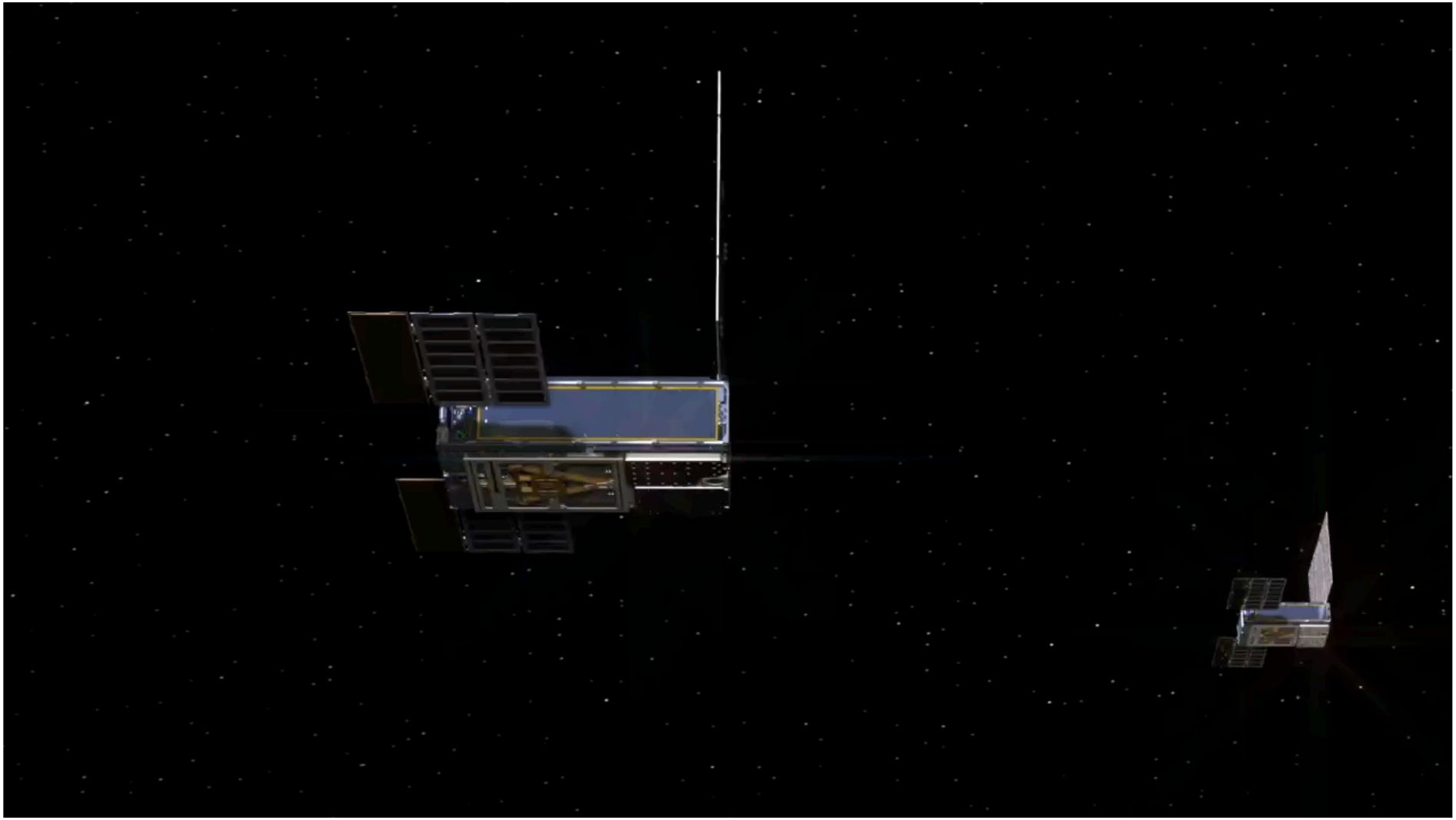
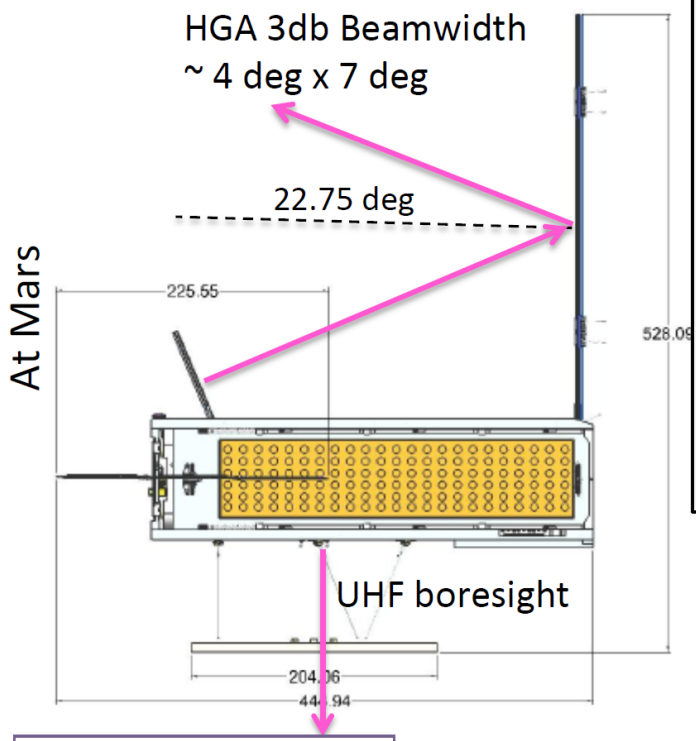
MarCO HGA Deployment



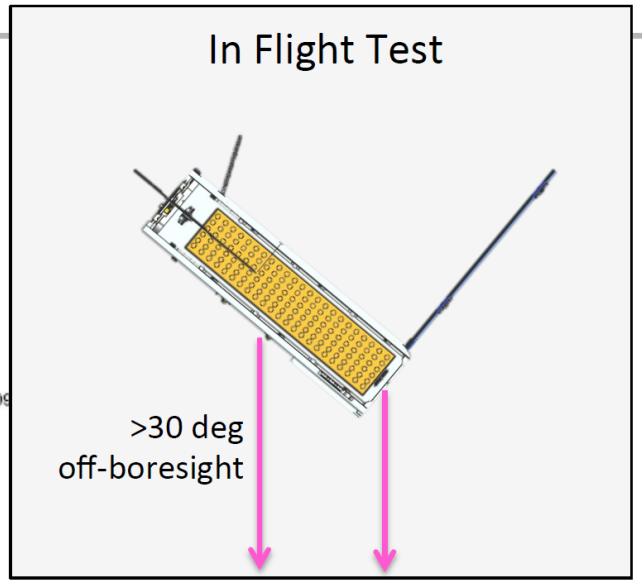
MarCO UHF Antenna Deployment

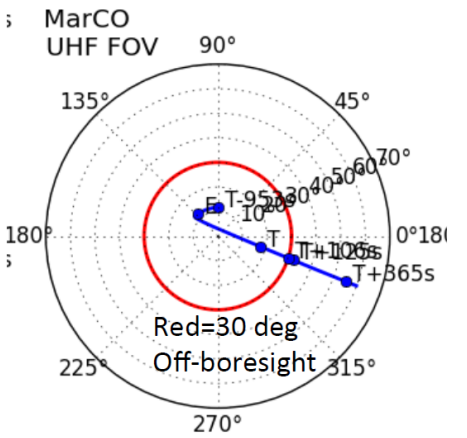


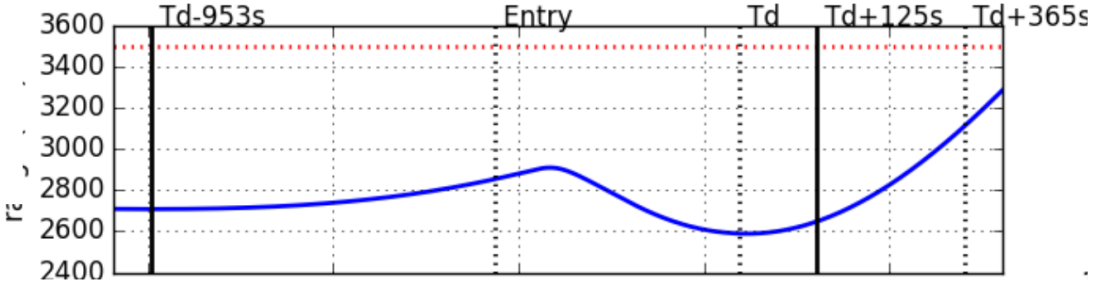
Bent Pipe Attitude

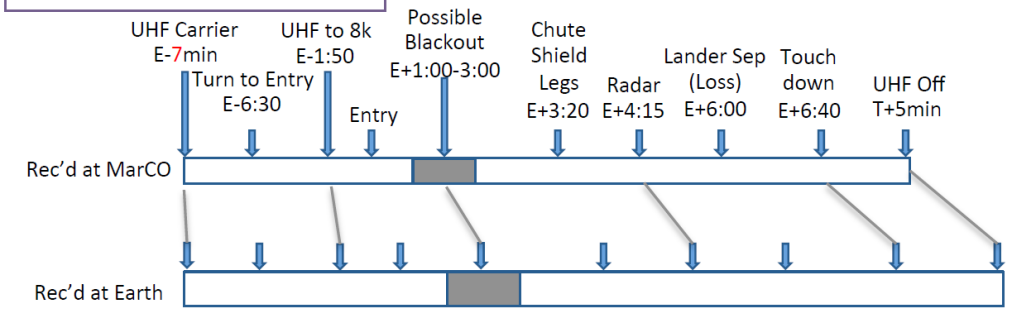


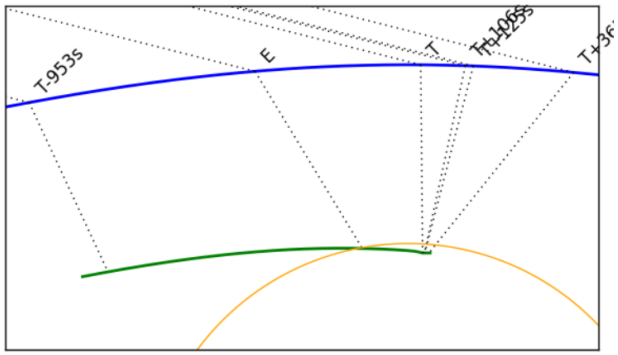
~15% "Overhead" on Bent Pipe:
MarCO Frame headers
+ Interleaved MarCO Data







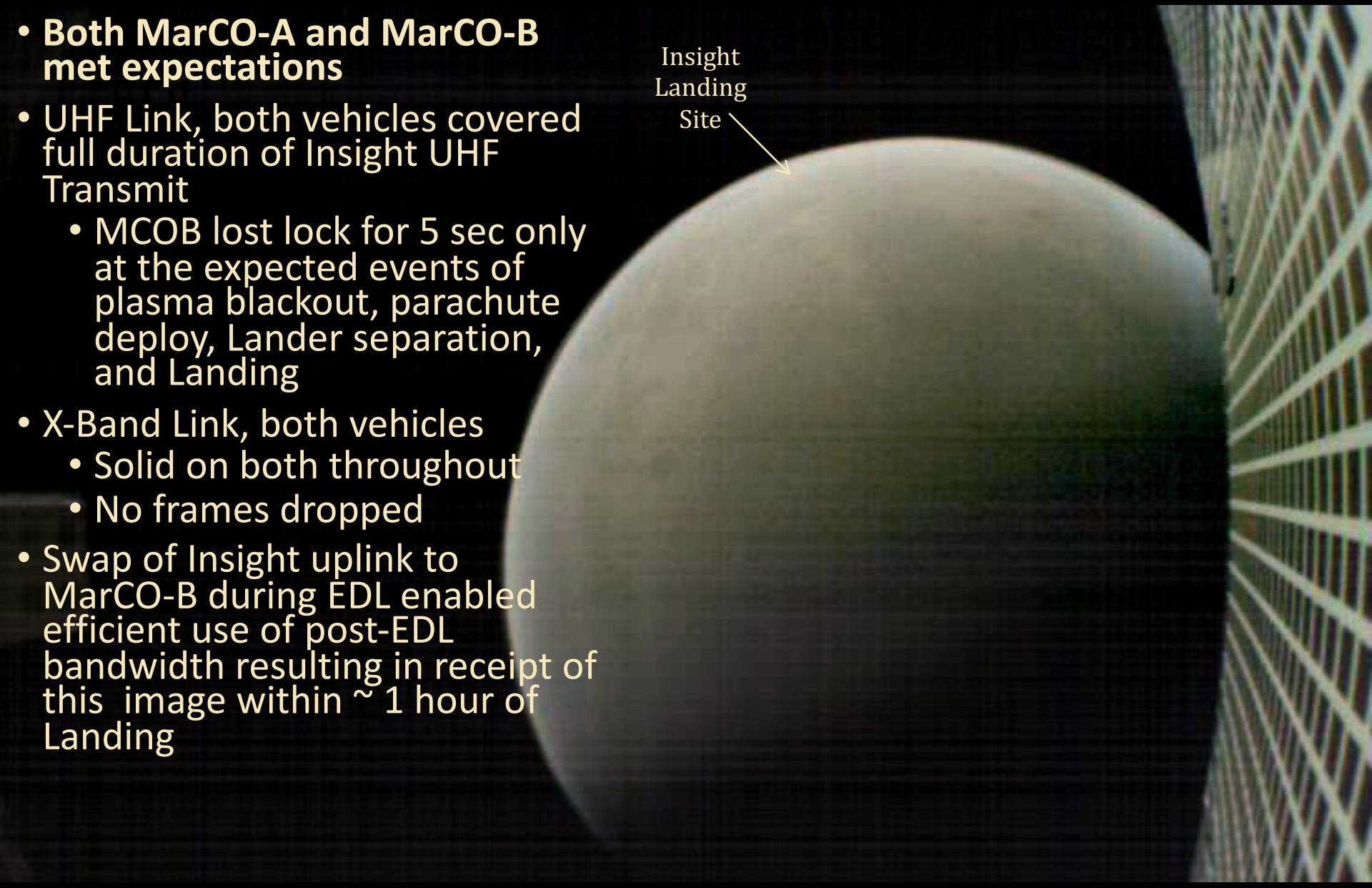




MarCO-InSight Relay

- Prioritization scheme based on packet type (APID)
  - InSight data would stream at a near continuous sense
  - 30 sec interrupts with a snapshot of MarCO health data and a 2 sec cadence history of relevant RF information
  - Anything not relevant for informing InSight about signal status was saved for later downlink.
- Could have maintained the 62.5 downlink to 70m DSN station using the MGA if HGA did not perform as expected
- Leveraged an optimized trajectory for relay performance - an advantage of the dedicated relay
- Able to rely on commercial equipment since only need to support the relay once (not staying in orbit)
- Add redundancy in sending two spacecraft (uncertainty in both MarCO performance and final InSight EDL trajectory)

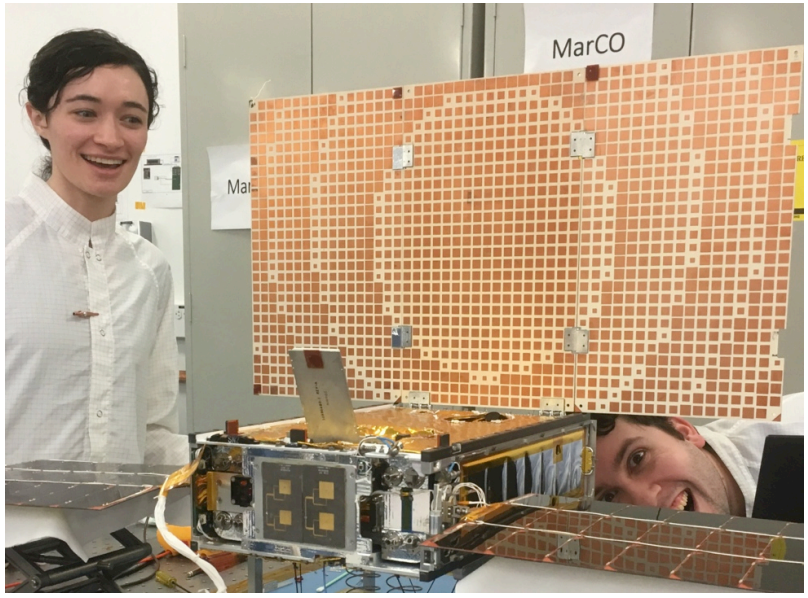
- **Both MarCO-A and MarCO-B met expectations**
- UHF Link, both vehicles covered full duration of Insight UHF Transmit
  - MCOB lost lock for 5 sec only at the expected events of plasma blackout, parachute deploy, Lander separation, and Landing
- X-Band Link, both vehicles
  - Solid on both throughout
  - No frames dropped
- Swap of Insight uplink to MarCO-B during EDL enabled efficient use of post-EDL bandwidth resulting in receipt of this image within ~ 1 hour of Landing



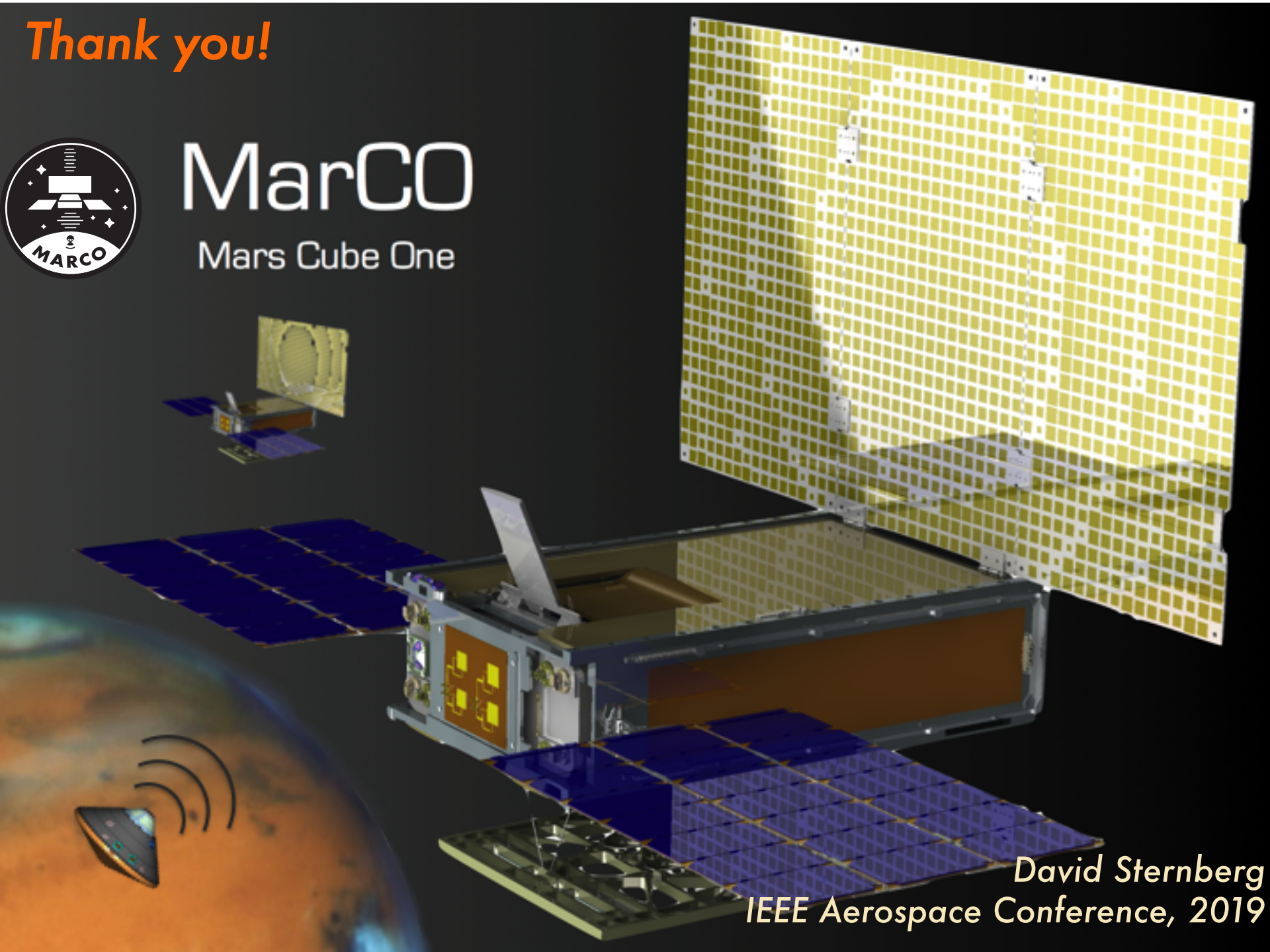
MarCO-B Wide FOV Camera Image, 26 November 2018; DOY330T20:10:00, ~ 6000km range

Conclusions

- Consider in the future:
  - Dedicated small spacecraft can support critical events when too costly or infeasible for others to perform the relay
  - Small spacecraft can be sent in multiples to provide improved coverage or signal reliability
- Lesson Learned:
  - single uplink frequency for both
  - Had end to end simulation for both X band and UHF
  - In-space test with SRI (46m), Morehead was 21m



Thank you!



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